Research Square

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Body mass index in relation to prostate specific antigen-related parameters

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Abstract

Purpose Only a few previous studies were conducted to assess the association between body mass index (BMI) and prostate-specific antigen (PSA) related parameters which take prostate volume (PV) and blood volume (BV) into consideration. The objective of this study was to assess the relationship between BMI and parameters of PSA concentrations in Chinese adult male.

Methods A total of 86,930 men who have taken annual physical examination at the First Affiliated Hospital of Army Medical University from 1 January 2011 to 31 December 2018 were included in this study. Partial Spearman correlation rank test was performed to assess the relationship between BMI, PV, BV and PSA, and analyze the correlation between BMI and PSA related parameters.

Results After adjustment for age, PV (correlation coefficient = 0.227, P-value < 0.001) was positively associated with PSA levels, while BMI (correlation coefficient = -0.057, P-value < 0.001) and BV (correlation coefficient = -0.041, P-value < 0.001) were inversely correlated to PSA concentrations. The analysis also indicated that BMI positively associated with PV and BV. Furthermore, the present study identified that PSA mass (correlation coefficient = 0.001, P-value = 0.763), after adjustment for age, was not affected by obesity in Chinese men.

Conclusion The findings of this large-sample, hospital-based study in China indicated that a higher BMI is associated with an increased PV and BV. BMI was negatively associated with PSA and PAS density, and no statistically significant association was found between BMI and PSA mass.

Background

Prostate cancer was a leading cause of death among men in the developed countries [1]. In 2012, 1.1 million men were diagnosed with prostate cancer worldwide, accounting for 15% of all cancer diagnosed in men according to the World Health Organization's International Agency for Research on Cancer [2]. However, screening for prostate cancer was one of the most hotly debated health care issues due to its controversial, overtreatment, psychological distress, and unnecessary medical costs [3].

Prostate specific antigen (PSA) is the most commonly predictor for early screening and diagnosis of prostate cancer although there are still some challenges with PSA test [4]. A relationship between obesity and low PSA levels has been identified in several studies [5-8]. Obesity plays a key role in developing abnormalities in sex hormone metabolism and insulin levels, as the excess accumulation of adipose tissue or body fat. However, the specificity of PSA is limited and the false positive rate is relatively high, as most men who undertake biopsy for elevated PSA levels are not diagnosed with prostate cancer [9]. The most accepted hypothesis in this respect was that the men with a higher BMI might have enlarged prostate [10,11] and blood volume (PV and BV) [8,12], which could lead to the underestimation or overestimation of serum PSA concentrations.

However, few large-scale studies in China were conducted to assess the association between BMI and screening and diagnosis parameters of prostate cancer, which take PV and BV into consideration. The aim of this study is to assess the relationship between BMI, PV, BV and PSA in Chinese men, and whether there is a PSA related parameter that was not affected by BMI based on the data collected in physical examination of the residents of southwest China.

Methods

Overall Study Design

From 1 January 2011 to 31 December 2018, 86,930 consecutive ostensibly healthy Chinese men have taken physical examination in the Health Management Department of the First Affiliated Hospital of Army Military Medical University. The inclusion criteria in this study were: physical examination, PSA test, and prostate ultrasound were performed; no obvious abnormalities in prostate ultrasound; no history of prostate cancer and prostate surgery.

Clinical Variables

The physical examination information for the recruited subjects were collected including age (year), height (cm), weight (kg), PSA level (ng/ml) and prostate volume (ml). BMI (kg/m^2) was defined as weight (kg) divided by the square of height (m^2). According to WHO's BMI grading standards for the Asia-Pacific region, the recruited subjects were divided into: normal weight (18.5 kg / m □ 23.9 kg / m^2), overweight (24 kg / m^2 □ 27.9 kg / m^2) and obese (BMI > 28 kg / m^2). Body surface area (m^2) = weight $^{0.425}$ × height $^{0.725}$ × 0.2025. BV (L) = body surface area × 1.67 . PV (ml) = left and right diameter × front and back diameter × up and down diameter × 0.52. PSA density (mg) = PSA / PV. PSA mass = PSA × BV. A blood sample was obtained for serum PSA. All anthropometric measurements were made by trained observers using standardized techniques. All participants signed informed consent documents approved by institutional review boards.

Statistical Analysis

Partial Spearman rank test was used to test the pairwise correlation among the variables. The SPSS 20.0 software (SPSS, Inc, Chicago, IL) was used for statistical analysis and $P < 0.05$ was considered significantly for all analysis.

Results

Baseline characteristics of participants

In the present study, all data collected from 86,930 men were analyzed. The average age was 46.39 years, the average BMI was 25.01 kg / m^2, the average PSA level was 0.65 ng / mL, the average PV was 18.43 mL, the average PSA density level was 0.04 mg, the average BV level was 2.97 L, and the average PSA mass level was 1.91 mg, respectively. The minimum and maximum values of these variables were also presented. The demographics of the study population are listed in **Table 1**.

Table 1 Characteristics of the study population

	n	Minimum	Maximum	Mean	SD
Age (years)	86, 930	18	475	46.39	12.22
Height (cm)		103.00	202.00	166.67	6.29
Weight (kg)		40	171	69.53	9.72
BMI (kg/m^2)		18.5	63.0	25.01	3.00
PSA (ng/ml)		0	33	0.65	0.74
PV (ml)		0.137	189.82	18.43	6.73
PSA density (µg)		0	9	0.04	0.05
BV (L)		2	5	2.97	0.23
PSA mass (µg)		0	95	1.91	2.10

Notes: BMI, body mass index; PSA, prostate specific antigen; PV, prostate volume; BV, blood volume; SD, standard deviation.

Correlation among BMI, BV, PV and PSA levels

Spearman rank test results showed that BMI (P < 0.001) and BV (P < 0.001) were negatively associated with PSA, but PV (P < 0.001) was positively associated with PSA after adjustment for age (**Table 2**), indicating that PSA levels was affected by BV, PV and BMI. Furthermore, BV (P < 0.001) and PV (P < 0.001) were positively associated with BMI after adjustment for age, indicating that a higher BMI might have a larger PV and BV. Particularly, BV and PV most likely showed the positive association with BMI and PSA, respectively.

Table 2 Pairwise correlation among the variables after adjustment for age

	BMI	BV	PV
BMI	-	-	-
BV	0.651$^{\square}$	-	-
PV	0.061$^{\square}$	0.115$^{\square}$	-
PSA	-0.057$^{\square}$	-0.041$^{\square}$	0.227$^{\square}$

Notes: BMI, body mass index; PV, prostate volume; BV, blood volume; PSA, prostate specific antigen; $^{\square}$means $P <$ 0.05

Correlation among BMI and PSA-related parameters

Table 3 showed the relationship between BMI and PSA, PSA density and PSA mass in different BMI categories. BMI was negatively associated with PSA (all sample: correlation coefficient = -0.057, P-value < 0.001; Normal weight: correlation coefficient = -0.026, P-value < 0.001; Overweight: correlation coefficient = -0.031, P-value < 0.001; Obese: correlation coefficient = -0.057, P-value < 0.001) and PSA density (all sample: correlation coefficient = -0.095, P-value < 0.001; Normal weight: correlation coefficient = -0.019, P-value < 0.001; Overweight: correlation coefficient = -0.022, P-value < 0.001; Obese: correlation coefficient = -0.036, P-value < 0.001) in all categories (**Table 3**). However, no significant association between BMI and PSA mass was detected in all categories (all sample: correlation coefficient = 0.001, P-value = 0.763; Normal weight: correlation coefficient = 0.008, P-value = 0.145; Overweight: correlation coefficient = -0.003, P-value = 0.497; Obese: correlation coefficient = -0.005, P-value = 0.554) (**Table 3**).

Table 3 Partial Spearman correlation among the variables after adjustment for age

BMI category	PSA		PSA density		PSA mass	
	Coefficient	p	Coefficient	p	Coefficient	p
All sample (n = 86930)	-0.057	<0.001	-0.060	<0.001	0.001	0.763
Normal (n = 32321)	-0.026	<0.001	-0.019	0.001	0.008	0.145
Overweight (n = 40779)	-0.024	<0.001	-0.022	<0.001	-0.003	0.497
Obese (n = 13830)	-0.031	<0.001	-0.036	<0.001	-0.005	0.554

Notes: BMI, body mass index; PSA, prostate specific antigen;

Discussion

In the present study, our results demonstrated that PV was positively associated with serum PSA concentrations, while BMI and BV were inversely related to PSA levels, indicating that BMI, BV and PV should be taken into account when recommending a patient to take prostate biopsy based on serum PSA concentrations. Furthermore, the present study demonstrated that a higher BMI might have a larger PV and BV. In addition, PSA-related parameters (PSA density and PSA mass) associated with different BMI categories were introduced in this study and it was demonstrated that PSA mass was not related to BMI in Chinese men.

Our results showed that serum PSA concentrations decreased with the increase in BMI among the participants who were not diagnosed with prostate cancer. This confirms the results from previous studies which have shown an inverse correlation between BMI and serum PSA [13,14,12,5-8]. Obesity plays a key role in developing abnormalities in sex hormone metabolism and insulin levels, as a result of the excessive accumulation of adipose tissue or body fat. It can lead to the benign prostatic enlargement by raising the estrogen and estradiol levels, while lowering testosterone and serum globulin binding protein levels [15]. The elevated estrogen/testosterone ratio associated with obesity might increase the stromal/epithelial cell ratio in benign prostatic hyperplasia nodules [16].

Previous studies have demonstrated that higher BMI might have larger BV [8,12] which could bias real serum PSA concentrations, and this finding was confirmed in the present study. The underlying hypothesis is that the amount of PSA released from cells in the prostate would be diluted to a lower concentration in men with larger BV in comparison with the one with smaller BV. Moreover, we found that the BMI was positively correlated with PV, whilst PV was positively correlated with the level of PSA. However, the BMI was negatively correlated with PSA level. One possible explanation is that, on one hand, higher BMI might cause larger PV and increase PSA levels. On the other hand, higher BMI could cause hemodilution because the BV has increased, and the hemodilution of blood volume on PSA was more remarkable than the increase in PSA caused by PV [8,17].

Based on the impact of BV and PV on PSA levels, it is necessary to make a comprehensive judgment by combining BV and PV. Some new PSA parameters had been proposed to eliminate the effects of these factors on PSA and improve the sensitivity and specificity of prostate cancer screening. We estimated PSA density and PSA mass, respectively, as PSA concentration divided by PV and PSA concentration times BV, showed that PSA density concentration have an inverse correlation with BMI, but PSA mass showed no significant correlation with BMI. Our analysis results indicated that using PSA mass to assess PSA concentration will not be affected by obesity in Chinese men. The previous study also showed that there was no association between BMI and PSA mass that relates to prostate cancer screening in our study.

There were some limitations in our study, such as being a cross section study. Second, because the study participants were Chinese, the data may not necessarily represent populations outside China. We have analyzed the data according to WHO's BMI standard grading system as it is globally recognized to assess somebody's weight. However, Asians have smaller skeletal frame and it is of significance to perform further analysis according to the BMI standard for Asian adults and compare the results of these two systems. Moreover, the study measures did not include total levels of testosterone, which an important indicator, as it was not routinely measured. The serum total testosterone is inversely associated with BMI, and obesity is usually directly associated with the low testosterone levels and causes many systemic illnesses. The present study neither performed analysis of other obesity indices except BMI. In addition, the socioeconomic factors and other potential confounders which might influence the BMI and PSA levels were not introduced into this study. However, our findings are consistent with those of numerous studies conducted in other regions and population.

Conclusion

The results of this large-sample, hospital-based study in China indicated that PV was positively associated with PSA concentration, but BMI and BV were inversely correlated to PSA concentration. Otherwise, PSA mass might be the best parameters to estimate the PSA concentration without the effect of obesity in Chinese general men.

Declarations

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Not applicable.

Authors’ Contributions

Zongtao Chen: Project development; Luling Chen: Manuscript editing; Dandan Lin and Ting Liu: Data Collection, Data analysis and Manuscript writing

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Availability of data and materials

The data of the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no conflict of interest.

Consent for publication

Not applicable

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study protocol was approved by the Ethics Committee of the first Affiliated Hospital of Army Medical University.

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